

X-513-64-353

NASA TMX-55154

FACILITY FORM 602

N65-18270

(ACCESSION NUMBER)

23

(PAGES)

TMX-55154

(NASA CR OR TMX OR AD NUMBER)

(THRU)

(CODE)

30

(CATEGORY)

# TRACKING OF A LUNAR TRANSFER ORBIT

BY

F. O. VONBUN

AND

W. D. KAHN

GPO PRICE \$

OTS PRICE(S) \$

Hard copy (HC)

Microfiche (MF)

\$1.00

\$0.50

NOVEMBER 1964



GODDARD SPACE FLIGHT CENTER

GREENBELT, MD.

TRACKING OF A LUNAR TRANSFER ORBIT

by

F. O. VONBUN AND W. D. KAHN  
GODDARD SPACE FLIGHT CENTER

## CONTENTS

|   |    |
|---|----|
| Summary . . . . .                                   | i  |
| Lunar Transfer Orbit . . . . .                      | 1  |
| List of Graphs (Comments and Explanation) . . . . . | 2  |
| References . . . . .                                | 19 |

## TRACKING OF A LUNAR TRANSFER ORBIT

by

F. O. Vonbun and W. D. Kahn  
Goddard Space Flight Center

### SUMMARY

18270

This study presents in essence a summary of the propagation of the position and velocity errors for a lunar transfer orbit. It was originally intended to show the errors of the orbit for the S-IVB instrumentation unit after kick-off. Therefore, tracking stations, such as Antigua and the Atlantic ship, have been selected for the orbit determination which are not optimized for this case.

The better station geometry for this example consisting of the Cape, Bermuda and Ascension would be reserved for the Apollo itself resulting in a better orbit determination.

Nevertheless, the graphs presented show the general trend and give a pessimistic idea for the expected errors for a lunar transfer orbit encountered during an Apollo Lunar Mission.

It should be pointed out however that no instrument bias errors are included in this report. A paper on the influence of bias errors upon orbit determination is in preparation.

18270 R →

# TRACKING OF A LUNAR TRANSFER ORBIT

by

F. O. Vonbun and W. D. Kahn  
Goddard Space Flight Center

## LUNAR TRANSFER ORBIT

The purpose of this study was to investigate the orbit determination capabilities of portions of the Apollo Ground Network (USB-System) for a typical lunar transfer orbit (see Figure 1). Injection is assumed to take place at the end of the second parking orbit over the Pacific. In particular, this study was directed to investigate the kick-off orbit of the instrumentation unit of the S-IVB after transposition.

Since the time of transposition,  $\tau$  (see Figure 2) is not exactly known at the present time, assumptions have been made that  $\tau$  will be 45 minutes, 60 minutes, and 75 minutes respectively. Using no a priori information (this means in essence that all the tracking information collected during the parking orbit and during the burn are not considered), the errors in position velocity are shown as a function of tracking time using 2 stations only; namely, Antigua and the Atlantic ship (insertion ship). For this case it has been assumed that the ship cannot determine the range. For the Antigua station, it was assumed that all 4 quantities; namely, range, range rate, azimuth, and elevation are available.

Also investigated is the effect of station location uncertainties in both the position and velocity of the instrumentation unit. Further shown is the effect of loss of the range information from Antigua and the increased angular errors of the insertion ship upon the precision and velocity.

As a matter of fact, the Apollo orbit will be known better since for this case Cape Kennedy, Bermuda, Antigua, and Ascension Island would be used for orbit determination of the manned Apollo. (Remember only 2 stations, Antigua and the ship are used for the curves presented in this paper.)

In order to make the graph easily understandable, all pertinent information is printed in the drawings itself. In addition each graph is explained and briefly discussed on a separate page.

## COMMENTS AND EXPLANATION OF THE GRAPHS

- Figure 1: This graph shows the lunar transfer orbit, two parking orbits as well as the stations used, namely Antigua and the Atlantic ship.
- Figure 2: This graph shows the tracking geometry for the lunar transfer orbit for a typical case and should be applicable for all lunar transfer phases.
- Figures 3 and 3a: These graphs show the position and velocity errors of the spacecraft as a function of tracking time. Each of the 3 curves represent a different time where the tracking is started depending on the time that  $\tau$  needed for the transposition. The curves show in essence a time translation of the errors only. Also indicated is that it takes at least 15 minutes using 6 measurements a minute to obtain reasonable values in position and velocity errors. (Beginning of the curve.) No station location errors have been assumed for this case.
- Figures 4 and 4a: These graphs represent the same curves as the graphs of Figures 3 and 3a but include 150 meters total error for the Antigua and 450 meters total error of the Atlantic ship. As seen, these location errors do influence both position and velocity of the spacecraft.
- Figures 5 and 5a, 6 and 6a, 7 and 7a: These figures show the position and velocity errors with and without station location for different times of tracking; that is, for different times lengths of the transposition phase.
- Figures 8 and 8a: These graphs are similar to those in Figures 3 and 3a. Only the range error is decreased from  $\pm 30$  meters to  $\pm 15$  meters. As can easily be seen by comparison of these graphs, these reductions and the range error does not significantly contribute anything to the orbit determination.

- Figures 9 and 9a, 10 and 10a: These graphs show position and velocity errors assuming no range information but just range rate and angles. Figures 10 and 10a assume angular errors in the order of 1.2 mrad as compared to Figures 9 and 9a. The influence of the increased angular errors for this particular short tracking interval of the transfer orbit is evident.
- Figures 11 and 11a: These graphs show again the position and velocity errors but assume range rate measurements only; that is, no range and no angular information would be available. Again, 3 curves are presented, each associated with a particular transposition time.
- Figures 12 and 12a: These graphs are a continuation of 11 and 11a and indicate that if only range rate information would be available longer tracking time is necessary to reduce the errors to those of the previous graphs. (See Figures 3 and 3a for a comparison, but note that the range rate information error has been decreased.)
- Figures 13 and 13a, 14 and 14a, 15 and 15a: These graphs show the influence of the measurement quantities (range, range rate, angles and their combinations) used for orbit determination for transposition times of 45, 60, and 75 minutes respectively. They also give an indication of what reduction in measurements per minute does to the position and velocity errors.

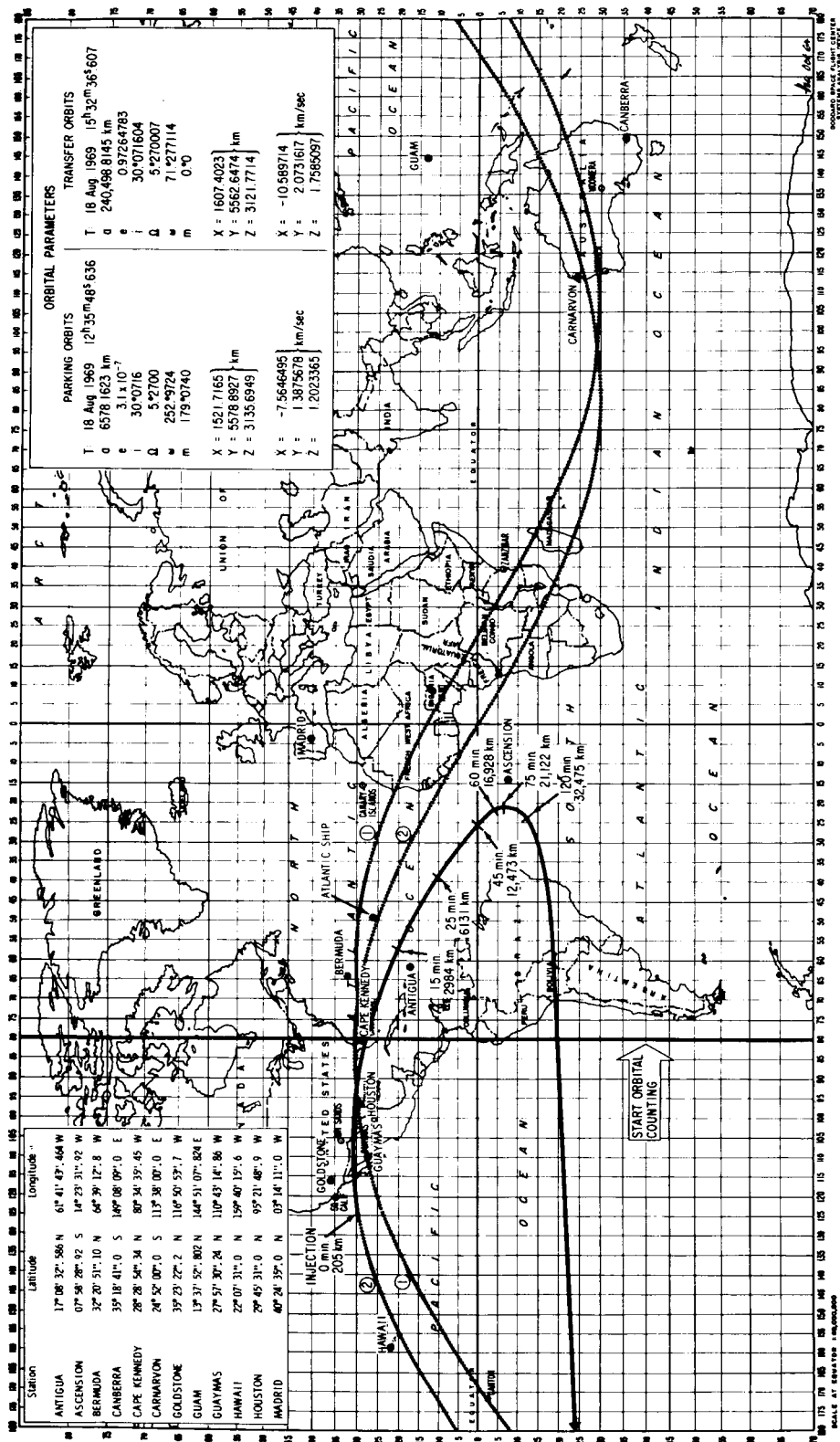
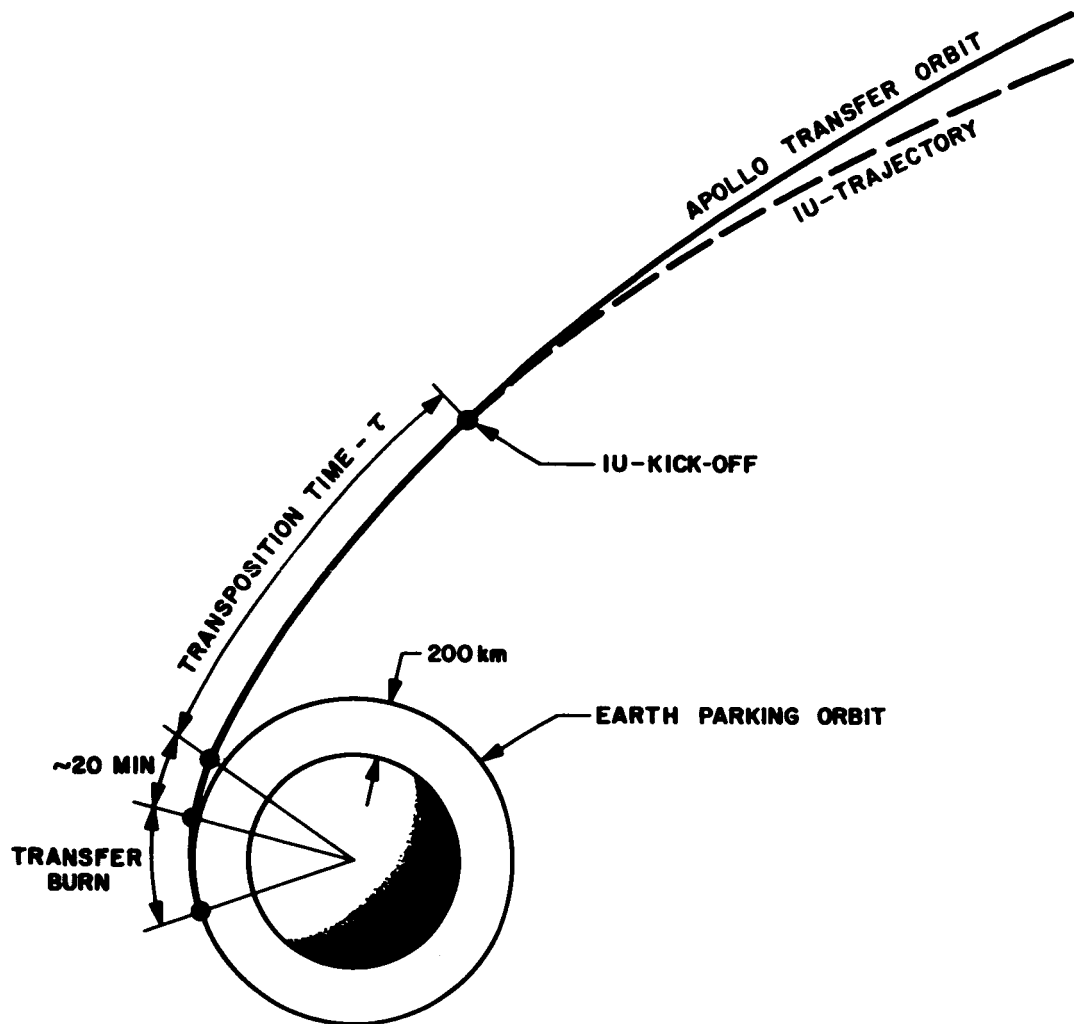


Figure 1—Lunar Transfer Orbit (second parking orbit injection).





## TRACKING GEOMETRY FOR LUNAR TRANSFER

GODDARD SPACE FLIGHT CENTER  
SYSTEMS ANALYSIS OFFICE  
OCT 1964

Figure 2—Tracking geometry for lunar transfer.

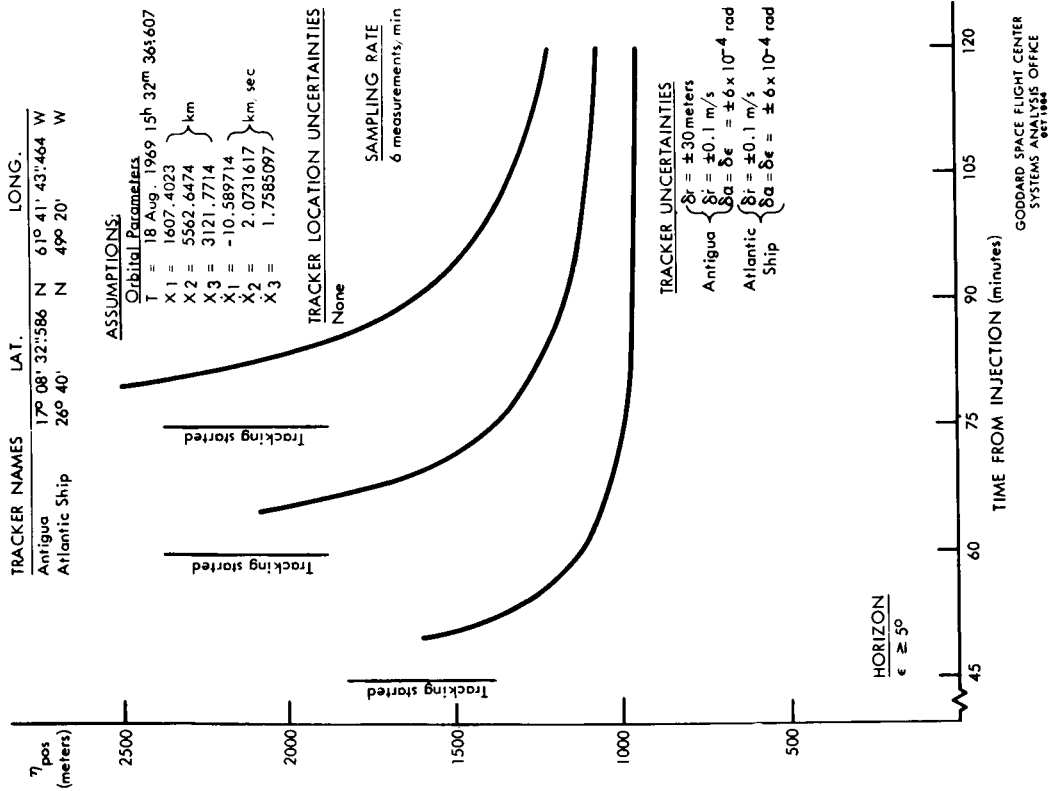


Figure 3—Error propagation in position during transfer orbit.

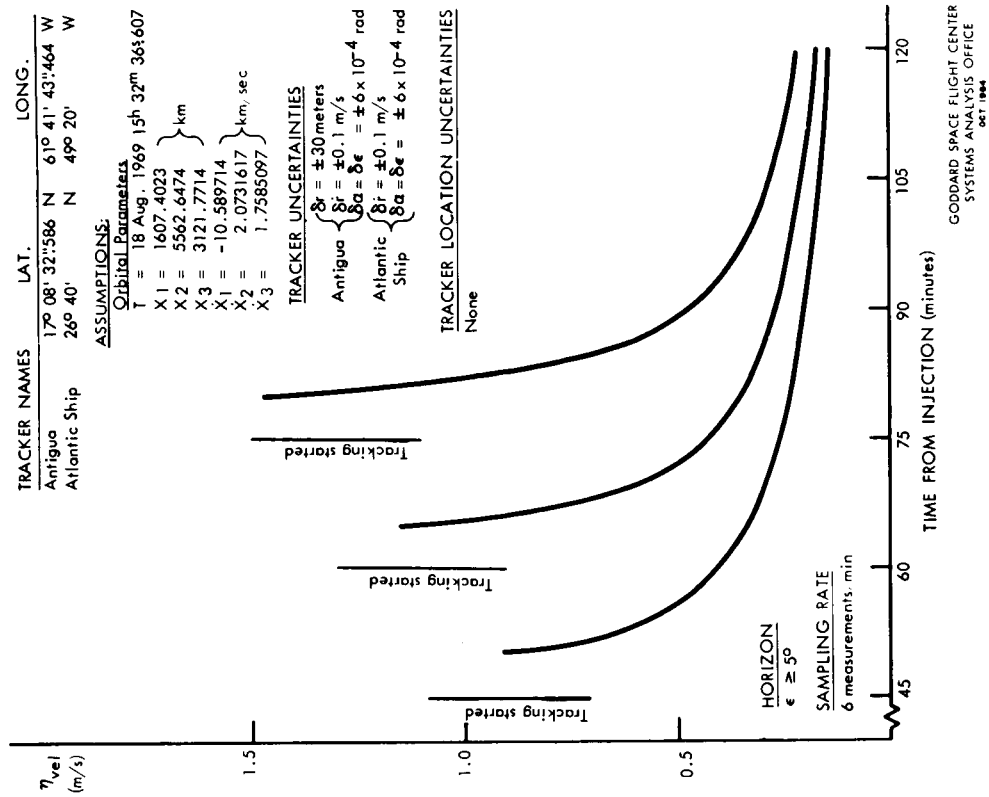


Figure 3a—Error propagation in velocity during transfer orbit.

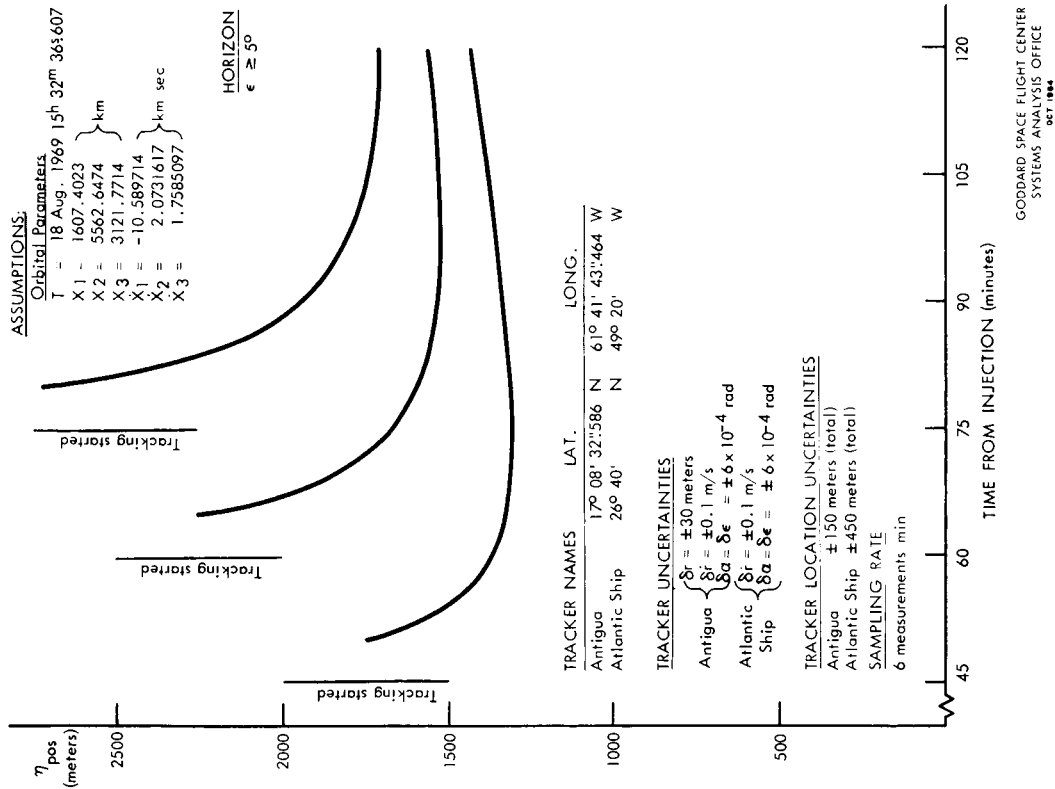


Figure 4—Error propagation in position during transfer orbit.

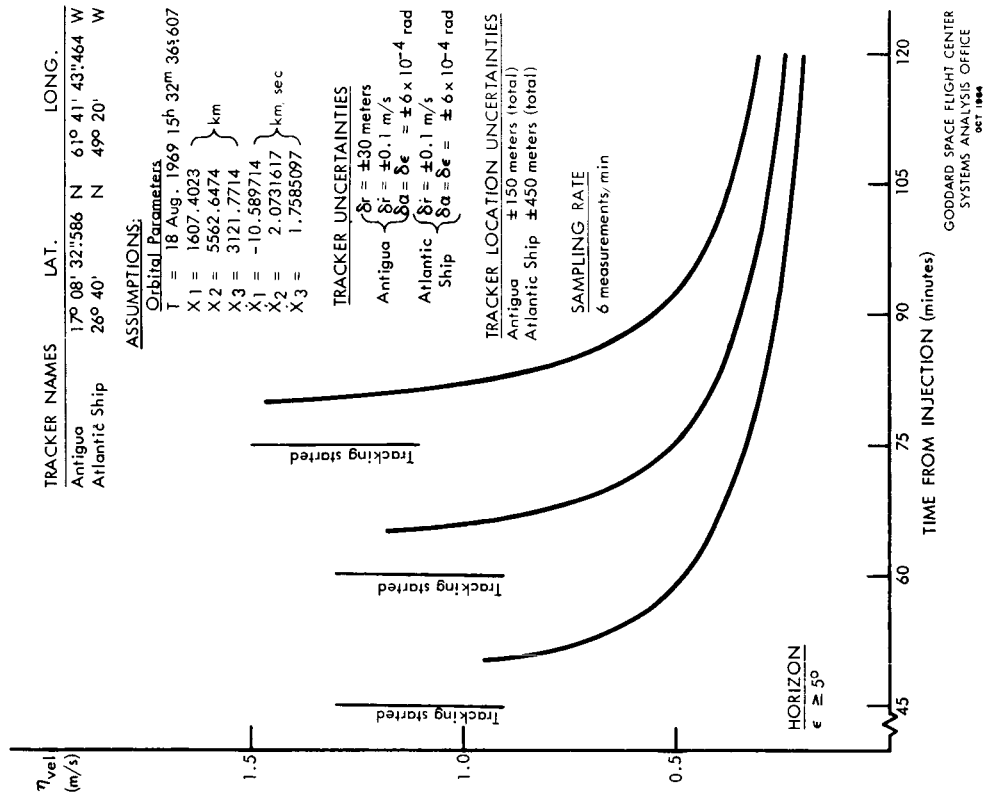


Figure 4a—Error propagation in velocity during transfer orbit.

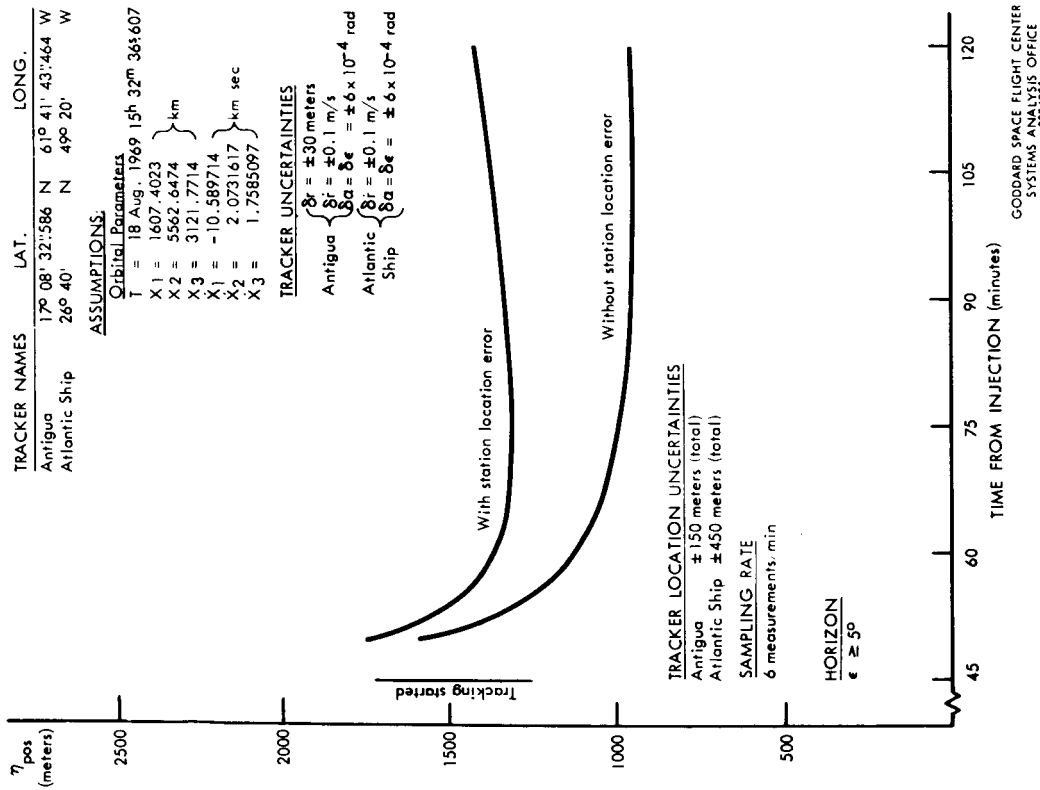


Figure 5—Error propagation in position during transfer orbit.

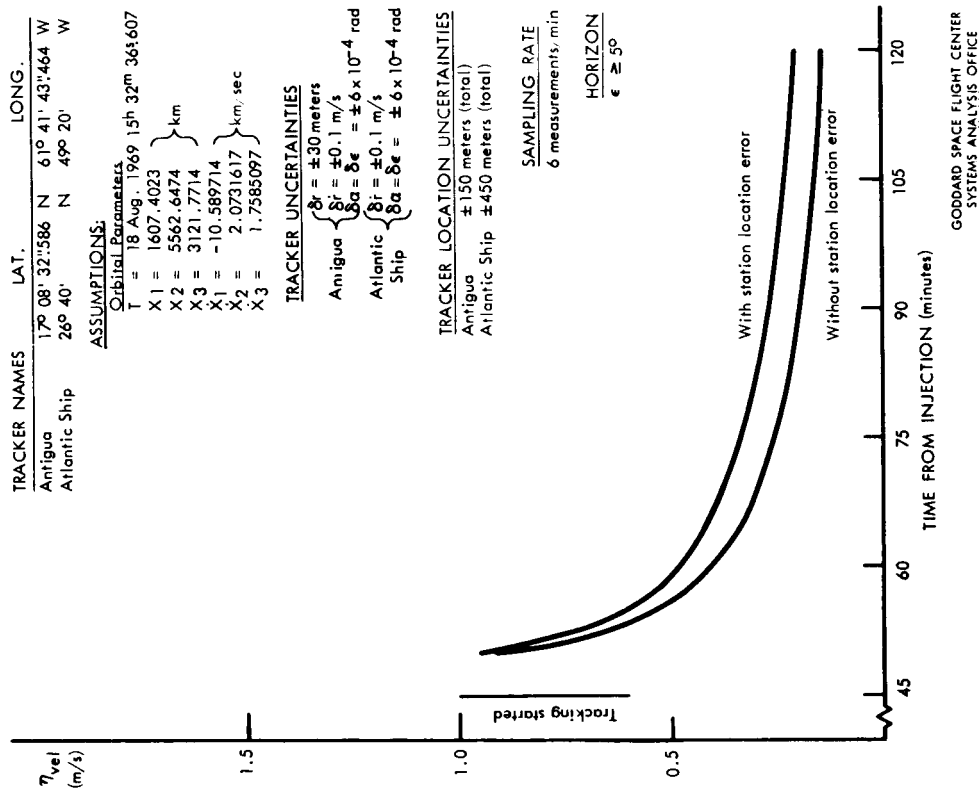


Figure 5a—Error propagation in velocity during transfer orbit.

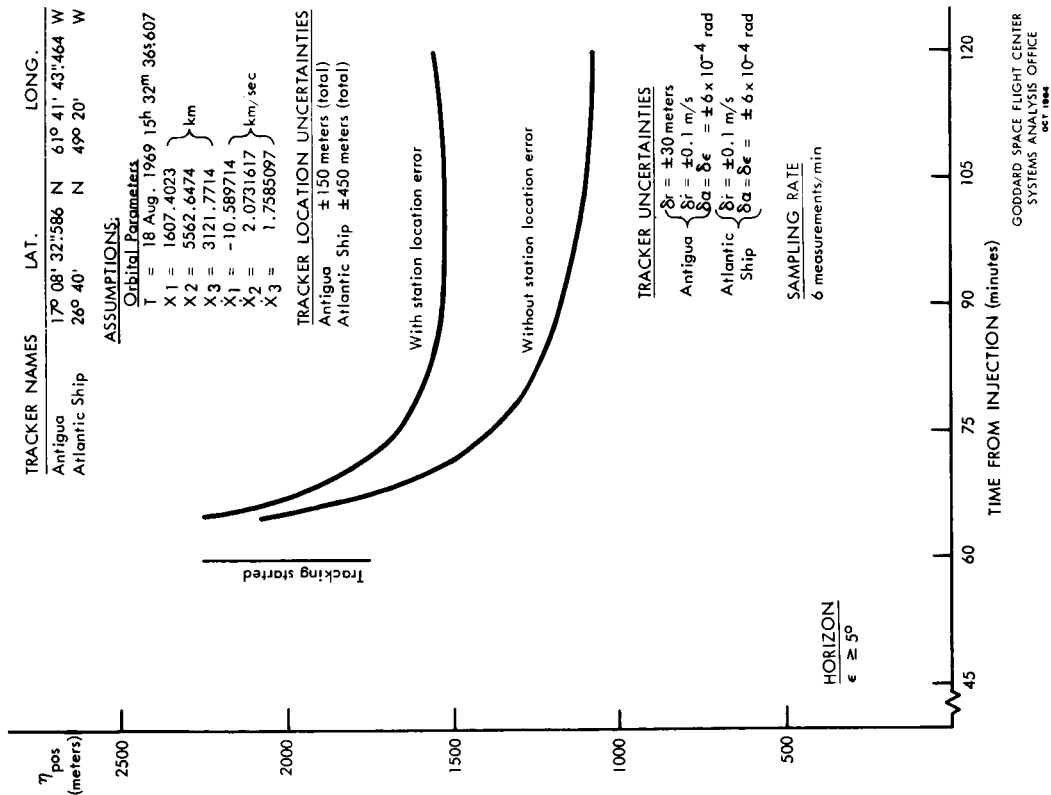


Figure 6—Error propagation in position during transfer orbit.

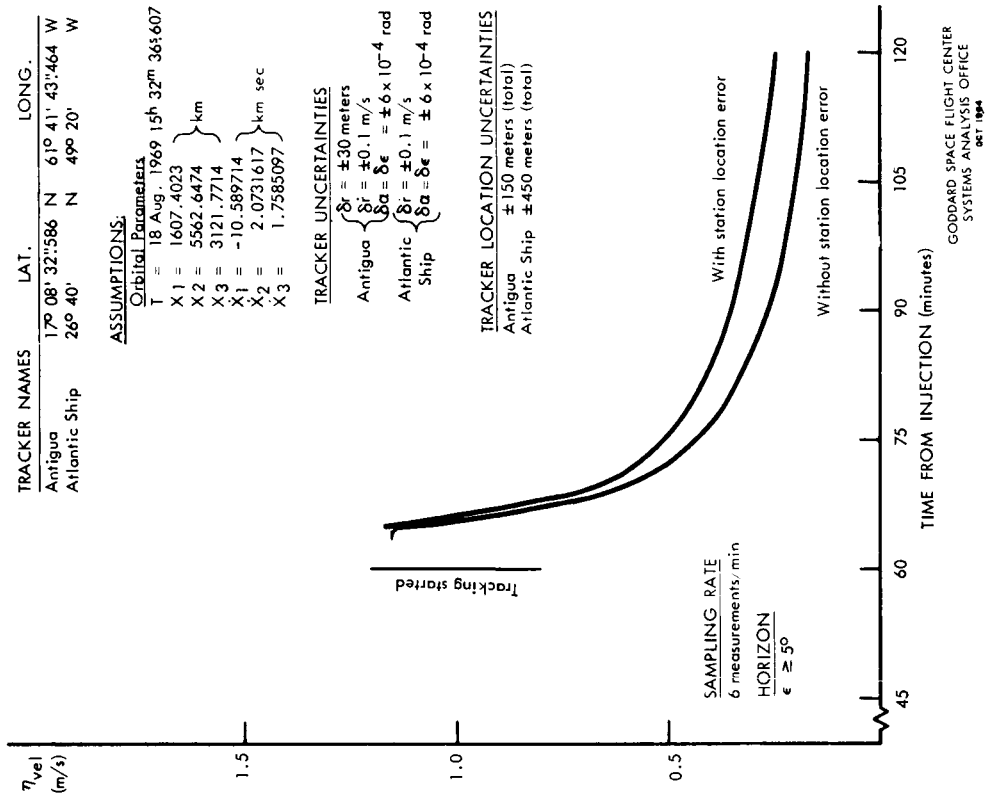


Figure 6a—Error propagation in velocity during transfer orbit.

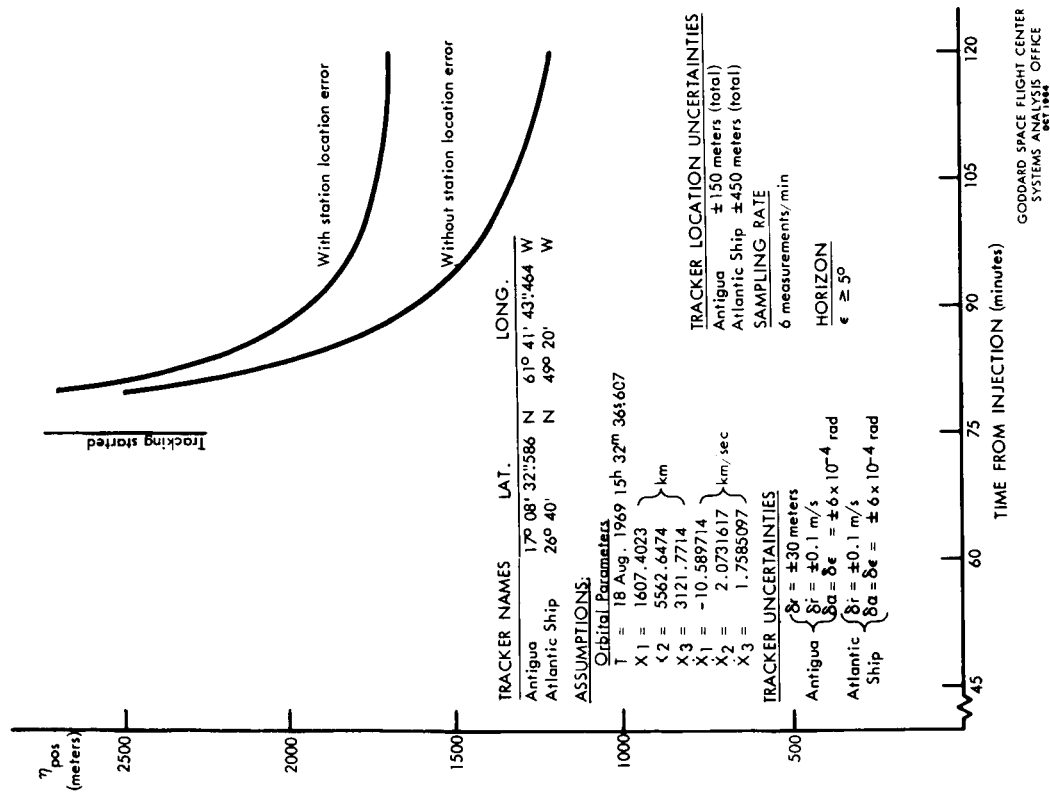


Figure 7—Error propagation in position during transfer orbit.

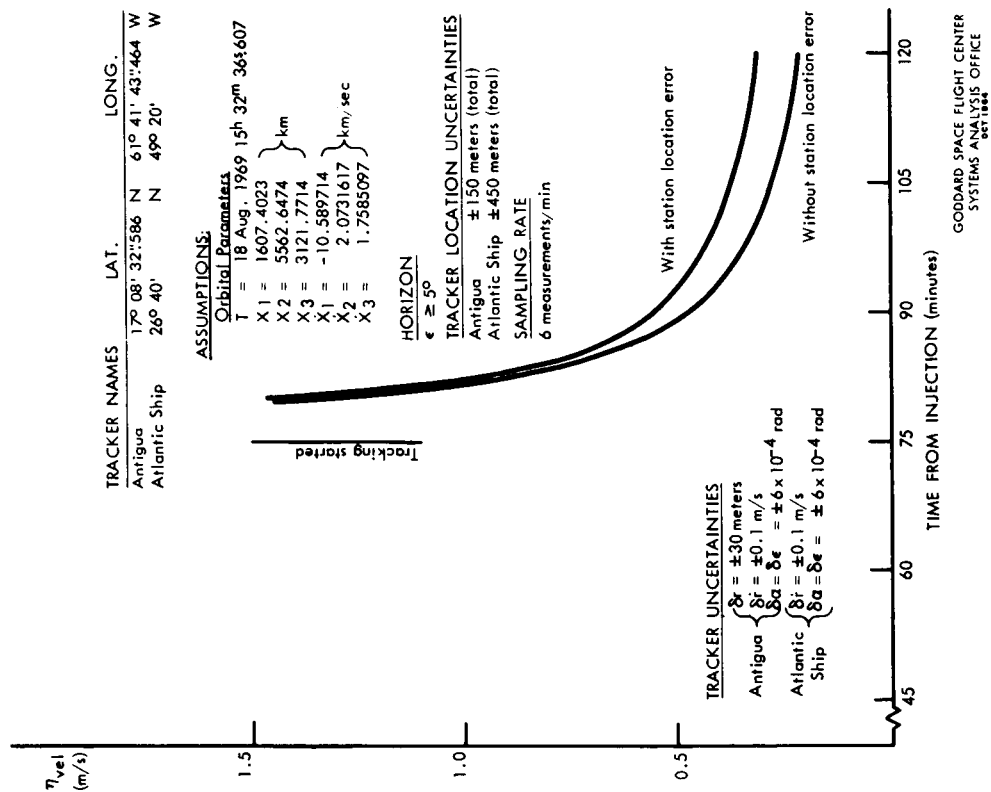


Figure 7a—Error propagation in velocity during transfer orbit.

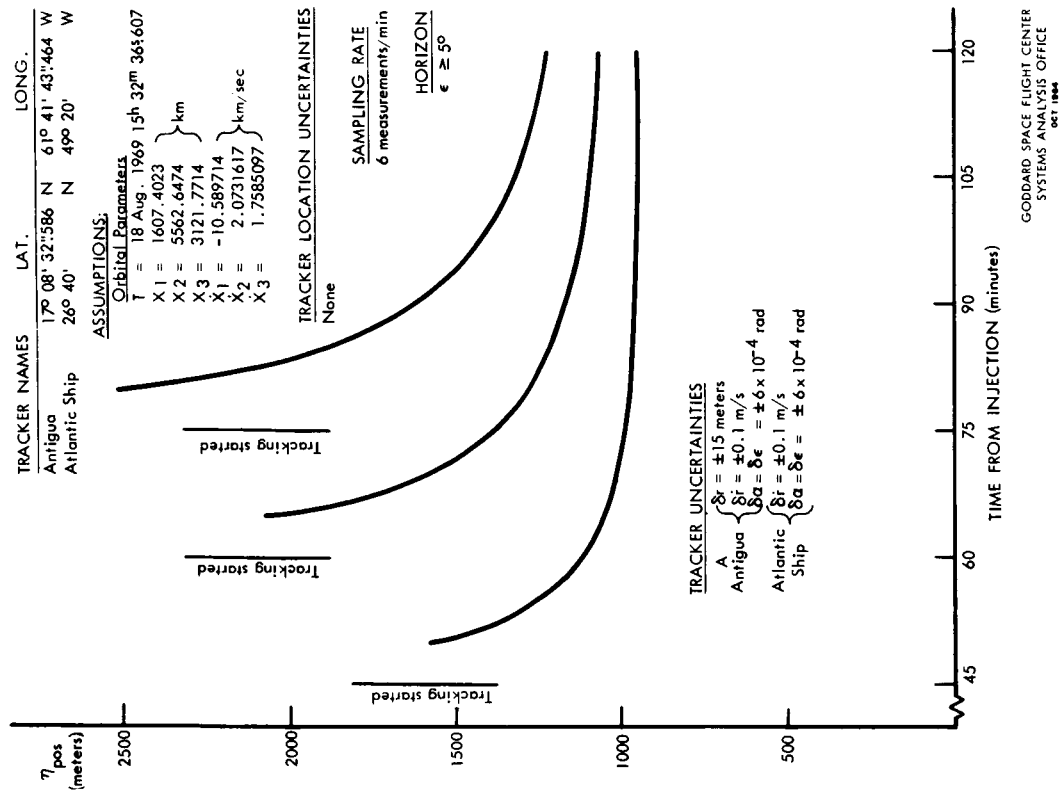


Figure 8—Error propagation in position during transfer orbit.

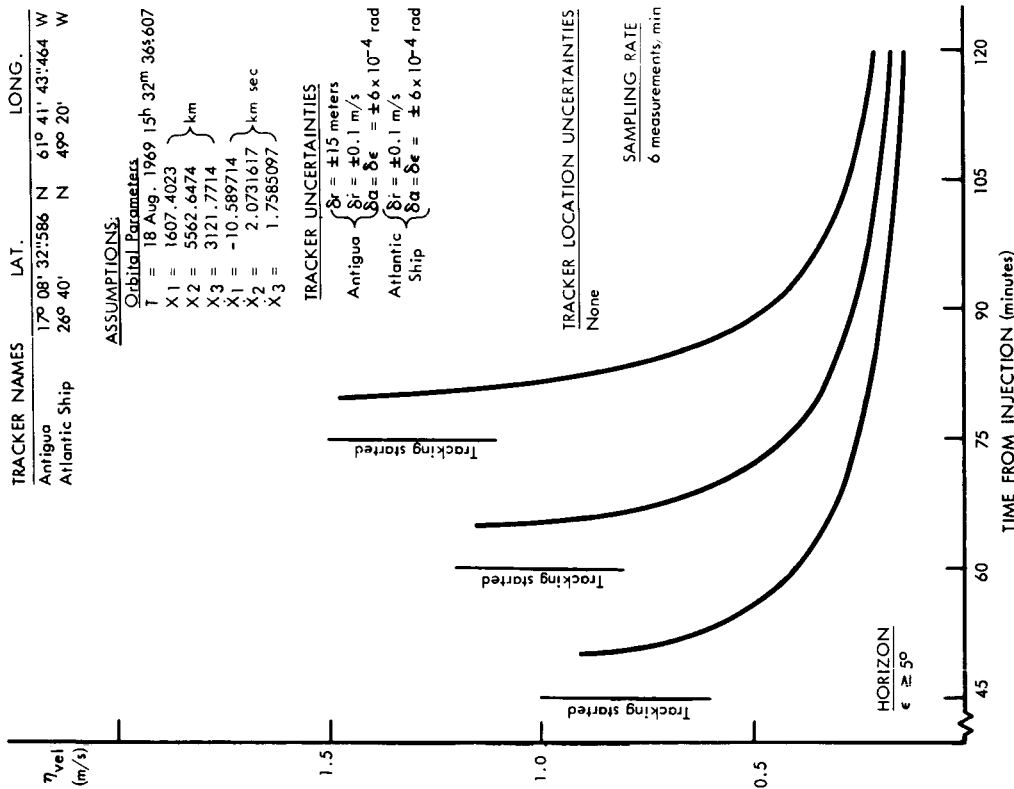


Figure 8a—Error propagation in velocity during transfer orbit.

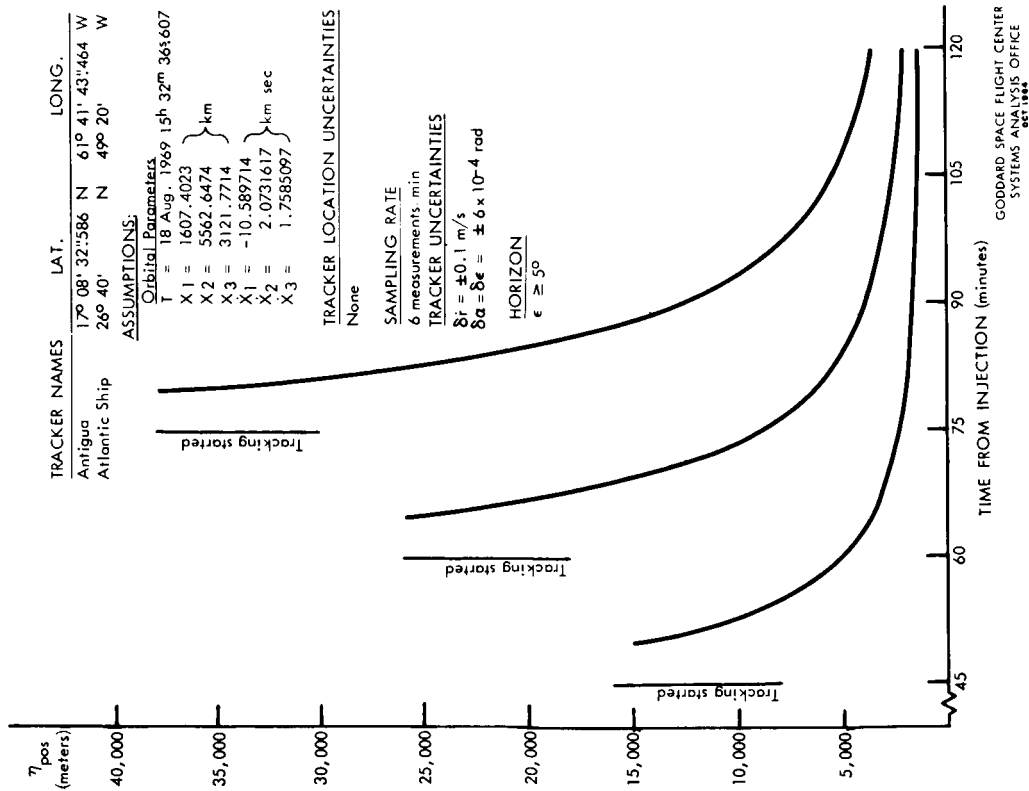


Figure 9—Error propagation in position during transfer orbit.

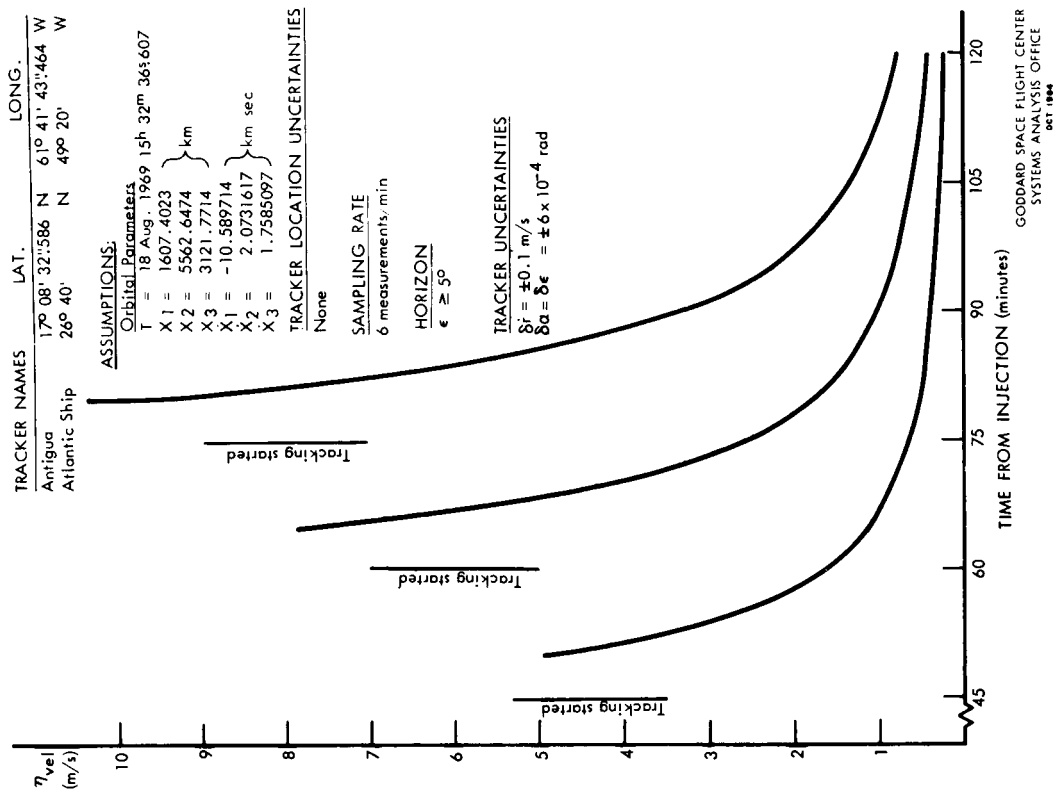


Figure 9a—Error propagation in velocity during transfer orbit.



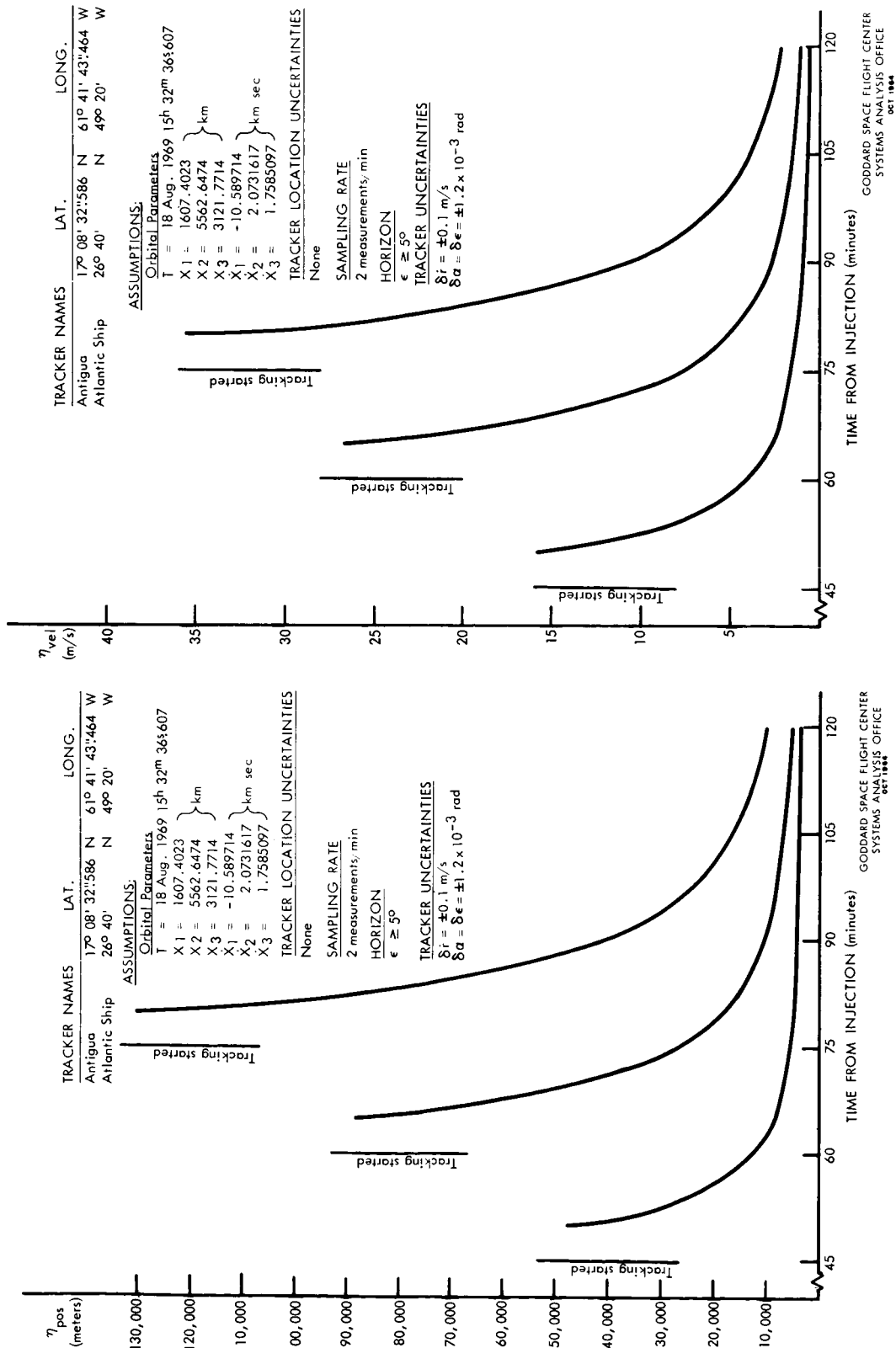


Figure 10a—Error propagation in velocity during transfer orbit.

Figure 10—Error propagation in position during transfer orbit.

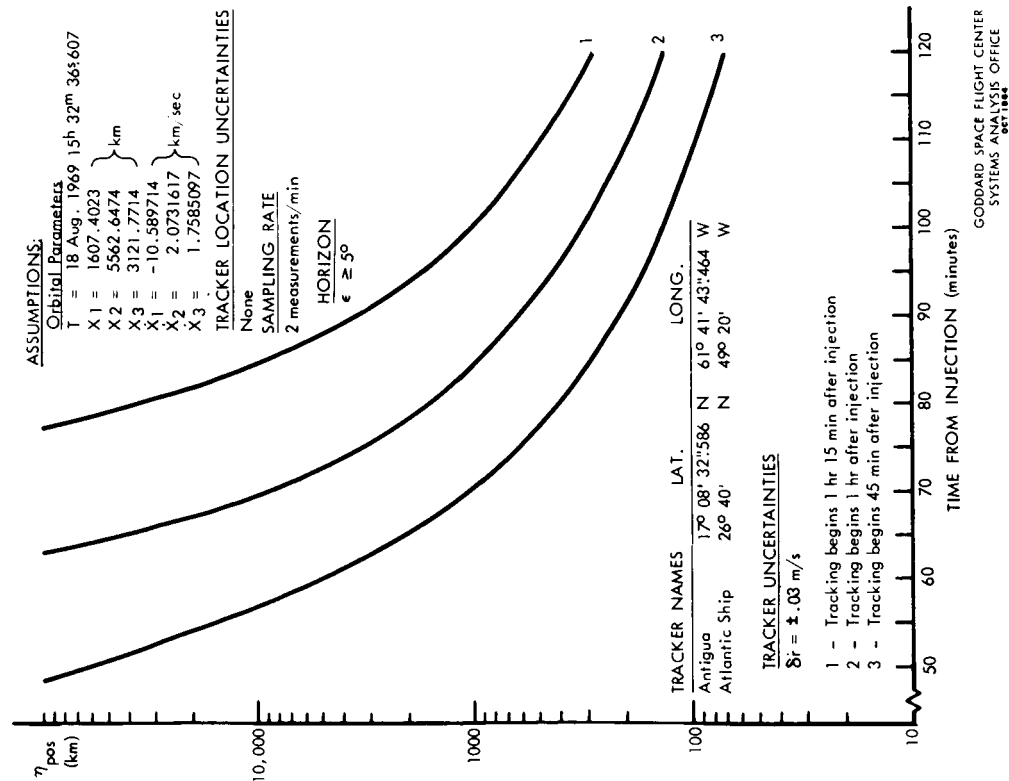


Figure 11—Error propagation in position during transfer orbit.

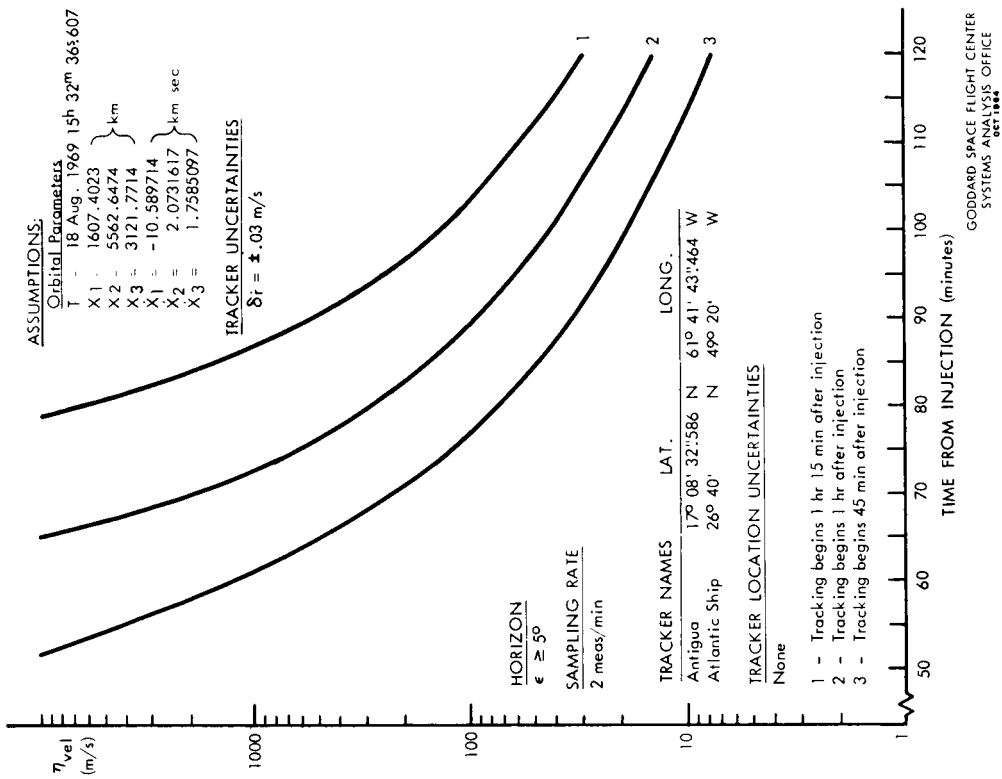


Figure 11a—Error propagation in velocity during transfer orbit.

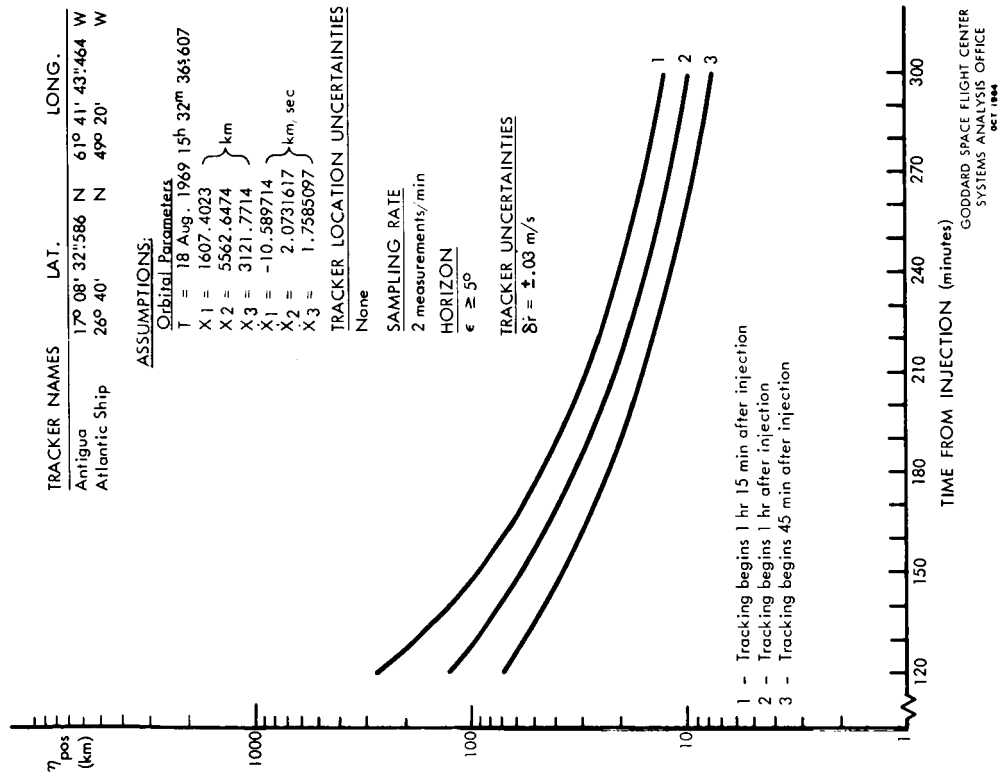


Figure 12-Error propagation in position during transfer orbit.

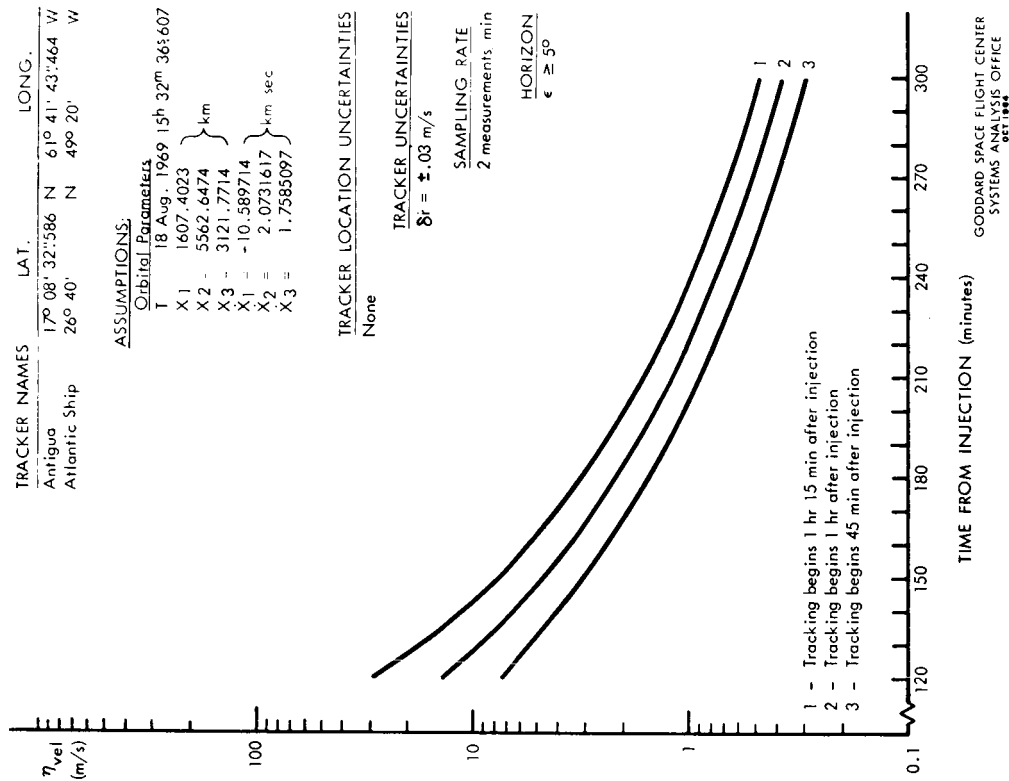
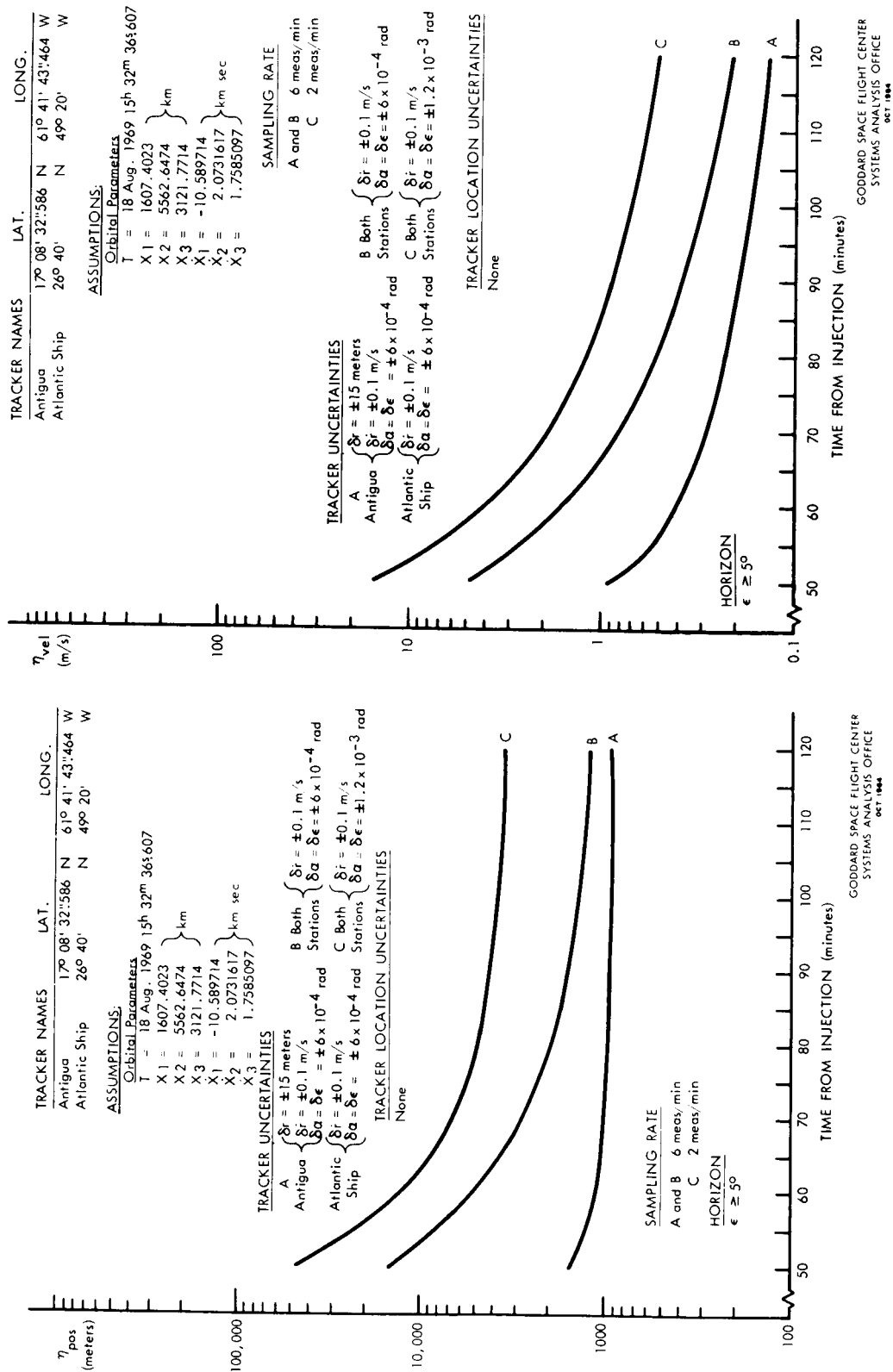


Figure 12a-Error propagation in velocity during transfer orbit.



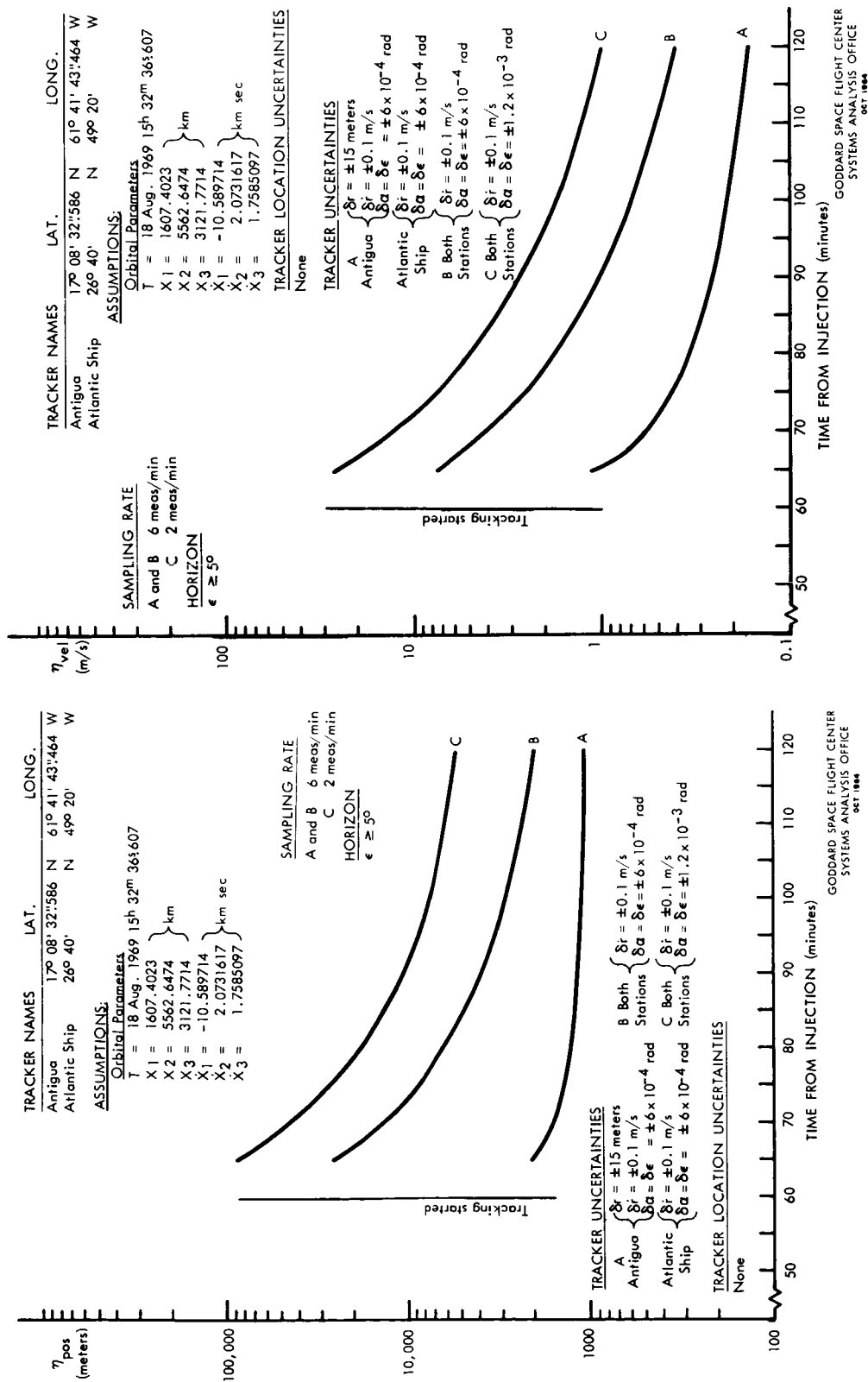


Figure 14—Error propagation in position during transfer orbit.

Figure 14a—Error propagation in velocity during transfer orbit.

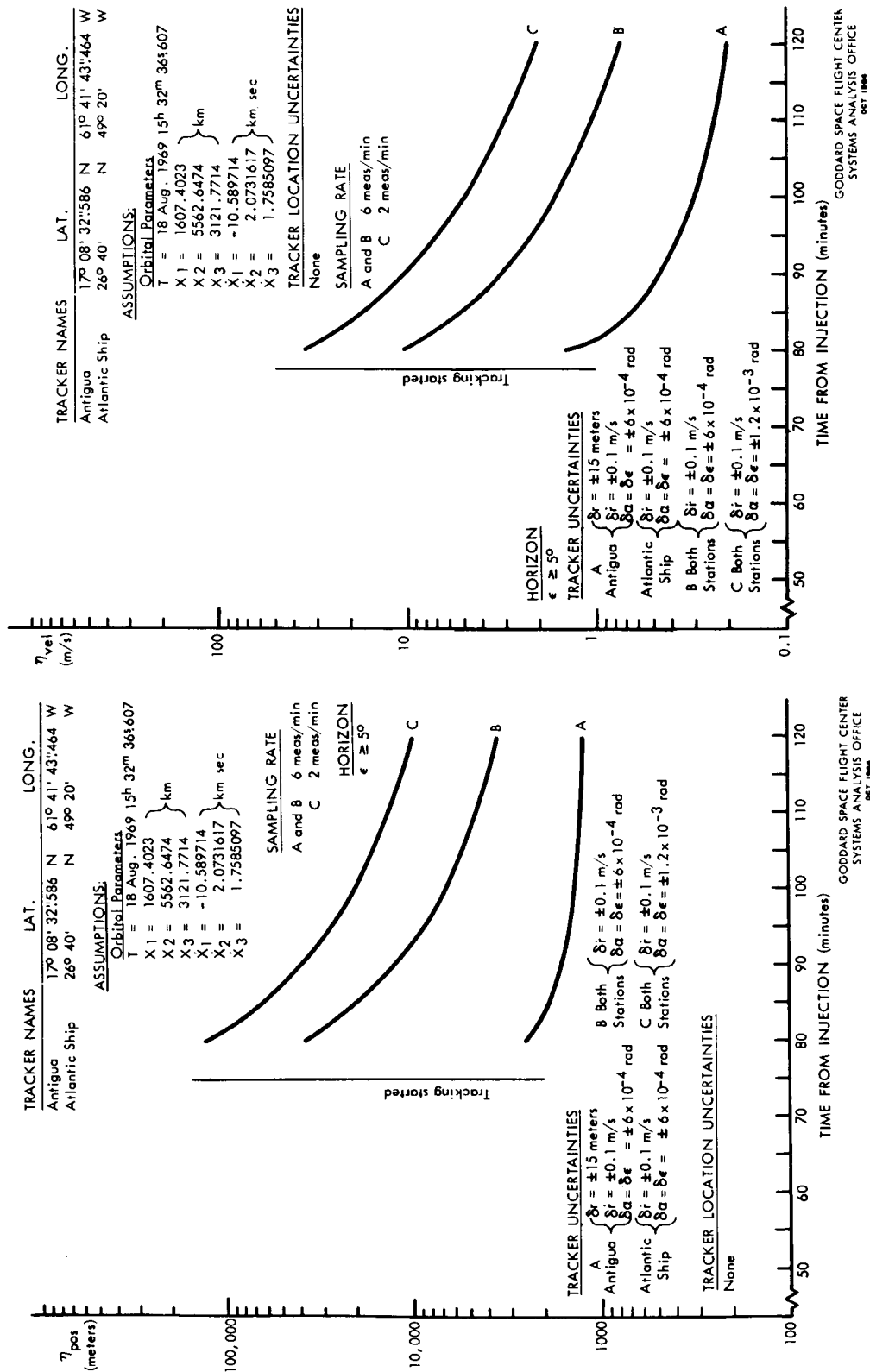


Figure 15—Error propagation in position during transfer orbit.

Figure 15a—Error propagation in velocity during transfer orbit.

## REFERENCES

1. Vonbun, F. O., and Kahn, W. D., "Tracking Systems, Their Mathematical Models, and Their Errors," Part I - Theory NASA Technical Note D-1471 October, 1962.
2. Kahn, W. D., and Vonbun, F. O., "Tracking Systems, Their Mathematical Models, and Their Errors," Part II - Least Squares Treatment; In Preparation.
3. Cooley, J. L., "Tracking Systems, Their Mathematical Models, and Their Errors," Program Description Goddard Space Flight Center, External Document X-513-64-145 May 10, 1964.
4. Philco Corp., Western Development Labs Users Manual & Programmers Manual for Interplanetary Error Propagation Program; Prepared for NASA, Goddard Space Flight Center Under Contract NAS-5-3342 November 15, 1963.